Multifunctional Photovoltaic Building Design And Efficient Photovoltaic Use Of Solar Energy

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Abstract:

Appropriate design and implementation planning of building integrated Photovoltaic offers potentials for multifunctional use and cost efficiency. Beside the generation of electricity from light, photovoltaic generators can be used for additional functions, which are for instance shading, electromagnetic energy conversion, electromagnetic shielding effectiveness, design, heating, climatisation, sound insulation, security, heat insulation and weather protection. Regarding the cost effectiveness of Photovoltaic installations these additional functions may play an important role. Therefore they should be considered and used consciously during the planning of building integration and installations. It is important to include the cost savings, which can be generated by the multifunctional use of photovoltaic components, e.g. by shading or weather protection, in the calculation of profitability. The integration of Photovoltaic in buildings should be considered as early as possible in the design process, desirably already during the preliminary draft. This is facilitating positive interactions between the specific building design and the efficient photovoltaic use of solar energy, including for instance also the use of preferably large sun-orientated building surfaces which are not shaded by building components or buildings. An integrated planning process facilitates the development of optimal solutions regarding design, functions and profits of buildings with integrated photovoltaic generators. The requirements for the integration of Photovoltaic in the building design affect particularly the subject areas "appropriate surfaces in facades and roofs", "integrated design with Photovoltaic and available components" as well as "building types and structural boundary conditions".

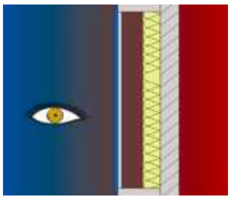
Keywords: building-integration, component, design, multifunctional, photovoltaic.

1. Introduction

Photovoltaic systems have the function to dissipate daylight - especially the high-energy direct solar radiation - in electric energy. This is true for systems, which are installed on open-land as well as for systems, which are integrated in the building envelope – in façades, roofs and additional components. [1] Potential multi-performance for additional use is based on the physical properties of the PV-component "module". Especially components, which are used for the substitution of common assembly parts, do include such multi-functionality. Such PV-components can be differentiated in bending-resistant (e.g. glass/glass- and glass/film-modules) as well as flexible devices (film-modules). At present, the assembly of PV-constructions in building envelopes is mostly carried out comparable with common components of so called glass architecture, with screwed, jammed or bonded splices on substructures, which are fixed on parts of the building, e.g. columns, slabs, outside walls, balconies or roofs. [2] The subsequently listed multiple functions of photovoltaic components are not always considered during the planning of building-integrated photovoltaic constructions. However they play, or can play, a significant role regarding the profitability of such constructions, if they would be used accordingly. Their applications and functions are depending on specific basic conditions, which can be assigned to specific building types. Besides the generation of electrical energy, photovoltaic can achieve the following functions: Blinds; Climatisation and efficiency; Design; Electro-magnetic energy conversion; Electro-magnetic shielding effectiveness; Heating; Light; Security; Shading and light direction; Sound insulation; Thermal insulation; Weather protection.

2. Multifunctional Photovoltaic

2.1. Blinds



Building integrated PV modules can serve also as blinds. While opaque PV-modules screen the components behind completely from view, the appearance of PV-modules with semitransparent cells (either amorphous or crystalline) is dark and reflective from the outside but transparent from indoor during the day. Therefore they function as one-sided blinds. The transparency depends on the size and the distance of the single photovoltaic cells to each other.

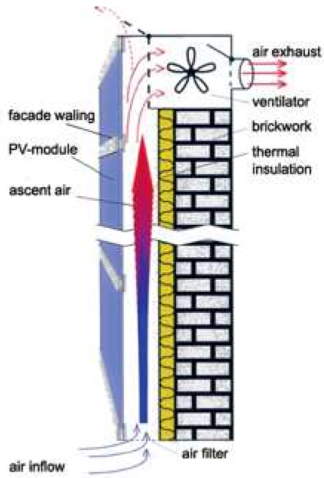
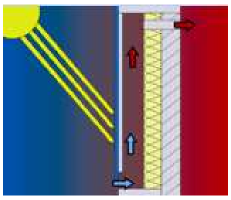


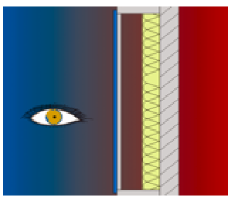
Illustration 1: Schematic Diagram of a rear ventilated PV-Façade. Investigations on a test-façade reconfirm a balanced energy balance between the generation of photovoltaic current and the increase of efficiency by simultaneous cooling of the rear side of photovoltaic components. The product is warm pouring air, which can be used for climate control [1]. [ISET]

2.2 Climatisation and module efficiency



Besides the generation of electricity the absorbed solar radiation warms up the PV modules. This heat can be utilized as thermal energy by rear-ventilation of the PV-modules in facades and roofs. At the same time an electric efficiency increase of the PV-modules occurs, caused by the cooling effect of the rear ventilation, so that it is possible to achieve energy balance in accordingly designed PV systems. In case of an optimized rear-ventilation, one could get in spring, and in transitional seasons respectively, a warm and pouring airflow free of charge. The thermal energy can be used for the heating of indoors. In summer the airflow would reduce the thermal load of the outer skin.

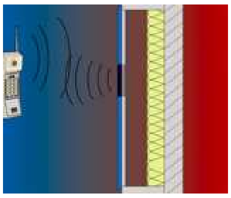
2.3 Design



Photovoltaic cells and modules are important design elements. They should be used in a sensible way and be integrated in the building design, based on architectonic considerations in all applications, as components as well as for the primarily use as electric generators. According to the specific architectonic concepts and desired optical effects, PV-components should be already considered during early building design phases. The look of PV-modules is amongst others dependent on the cell type (e.g. amorphous or crystalline), the cell structure (opaque or semi-transparent), the transparent cover (glass or plastics), as well as the size, the proportions and design of the single modules (e.g. with or without frames). Modules with amorphous as well as crystalline cells are available in many different designs and colours.

Illustration 2: Photovoltaic facade of a University building in Germany (left) [FHS Siblik] and a redeveloped residential building in Germany (right) [Rheinzink].

2.4 Electro-magnetic energy conversion



Specially designed PV-modules can be used for electro-magnetic energy conversion. These can be used e.g. for sending and receiving high-frequency signals for mobile phone communication. Solar planar antennas have been developed first in Germany in 1999 and were presented internationally in first pilot projects. Such building-integrated solar planar antennas can function as so called repeater-antennas in aesthetically challenging areas with poor reception (e.g. dead-spots in areas of multi-story buildings).

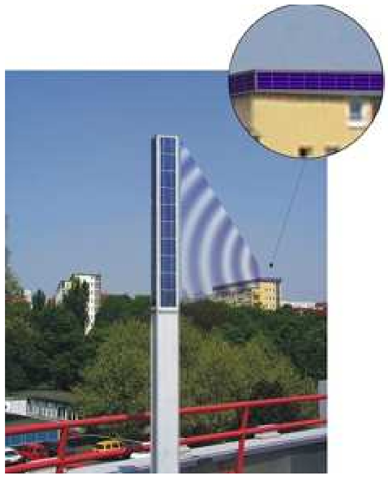
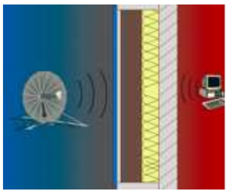


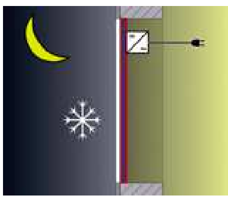
Illustration 3: Solar planar antenna: Design of a telecommunication route between a field gauging station and planar antenna in the area of a buildings attic. [ISET]

2.5 Electro-magnetic shielding effectiveness



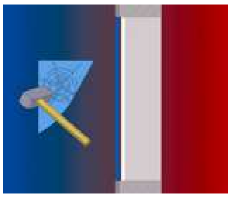
The electric network of the united cell structure and the conductive substructure of PV-modules cause a shielding effectiveness (faraday cage). This effect can be required for the protection of electric sensible areas, e.g. in hospitals, computer control-centers or buildings which are used for air traffic control. Electro-magnetic energy conversion and shielding effectiveness are not contradictory to each other if implemented with appropriate technical competence.

2.6 Heating



In general, the application of glazed roof lights above indoor courtyards requires also the application of heating devices near the glazed areas in the ceiling, to avoid the circulation of cold air and the generation of condensed water on the inside of the glazing. This effect should be avoided by the utilization of well-insulated glass with low thermal transmission coefficient. Generally it is required to scatter the direct sunlight to enhance the illumination of the indoor underneath and to avoid their overheating during hot seasons. Low cost solutions for the reduction of transmitted sunlight are based on the application of transparent coatings or paint on the glazing. If those skylights are substituted by special semi transparent PV-modules, they can produce electricity with solar radiation and shadow indoors underneath during the day. During the night and during cold outside temperatures they can avoid the circulation of cold air and the generation of condensed water on the insides of the roof lights, by feeding-in of reverse current in the PV-components and the resulting warming up of the glass component; accordingly the installation of additional heating devices can be avoided.

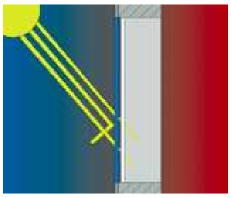
2.7 Security



PV-modules can incur the function of laminated safety glass due to the laminated assembly of toughened glass and foils. Additionally the electrical network of the photovoltaic modules can be used as an electric loop for a burglary safeguard.

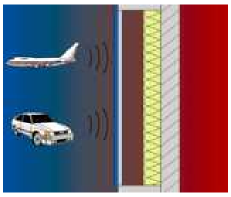
Illustration 4: PV-shed-roof: Photovoltaic shading (90%) with 10 % light entry by semitransparent amorphous PV-modules, which are integrated in the south orientated double-glazed shed-roof areas in the lounge of the local court in Kassel, Germany. [ISET]

2.8 Shading and light directing systems



In transparent glazing (single, double or triple glazing) PV-cells adopt the function of shading elements. The degree of shading can be decided by the different arrangement of cells in the module, or by the use of more or less transparent cells (crystalline or amorphous). Thereby, the degree of transmittance is arbitrary, e.g. between 10 and 90%. PV-modules in outside shading devices (e.g. light shelves, reflective blinds or prismatic components) adopt the function of shading for glazed building apertures, facades and roof surfaces. Additionally they can adopt certain light directing and redirecting functions to supply indoors with diffuse and reflected solar radiation.

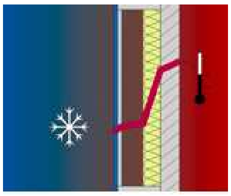
2.9 Sound insulation



Photovoltaic components in facades, windows and roofs contribute to the sound insulation, due to the laminated assembly and the good sound absorbing properties. The multi-layered sandwich body of common photovoltaic components can reach a sound reduction index of up to 25dB.

Illustration 5: Sound-insulating wall with PV-modules at a motorway. [Kohlhauer GmbH]

2.10 Thermal insulation

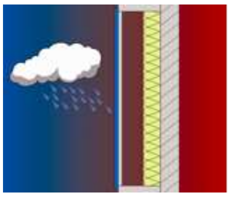


Insulation glass with integrated PV-cells, e.g. in windows, glass-facades and roofs, contributes to the heat insulation of buildings. These components meet all civil engineering requirements (like components with conventional insulation glass), and additionally they produce electricity.

PV-modules contribute to the heat insulation of buildings in large rear ventilated assemblies, in front of exterior walls and on roofs, as well as in rear ventilated facades as façade siding. "Intelligent" rear ventilated curtain type PV-facades use the air volume for thermal insulation (non ventilated state) or heat removal (ventilated state), using appropriate measurement and control technology.

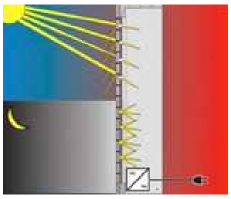
Illustration 6: Roof integrated skylight made of insulation glass components with semitransparent amorphous PV-cells in a showroom in Germany. [Glaswerke Arnold]

2.11 Weather protection



Photovoltaic components as water and wind-tight outer skin adopt the weather protection of roofs and façades. In rear ventilated roof and wall sidings the PV-components adopt the weather protection of the thermal insulation. Their assembly is equivalent to common glass components.

2.12 Light



Specially designed semi-transparent and *light-active* Photovoltaic modules facilitate the design and illumination of indoors with natural and artificial light with one component. Similar to semitransparent modules the transparent intermediate spaces between single PV cells, which proportions can be designed according to the specific requirements, allow the penetration of natural light in the indoors. Additionally, Light Emitting Diodes (LEDs), as well as light scattering or – directing elements are installed in the transparent areas of these components. The LEDs can be configured in a way that they substitute the natural light, which is used for the lighting of the indoors in the daytime, during the night. Furthermore these components can be also used for the exterior design of façades. For instance a combined installation of LEDs in red green and blue can be electronically controlled, and turn a façade in a colored monitor, which can be visible from outdoors and indoors.

3. Building integration of photovoltaic components

The building integration of photovoltaic components should be considered as early as possible during the design process of a building, desirably already during the preliminary draft phase. This facilitates the use of positive interactions between the specific building shape and the efficient photovoltaic use of the solar energy and includes the use of preferably big, sun-orientated building surfaces, which are not shadowed by building parts or other buildings. However, an integration of photovoltaic is in most cases also possible and explicitly desired, if these criteria can't be met completely. A basic condition for this purpose is an interdisciplinary cooperation of architects and specialist consultants for systems- and building services engineering and producers of photovoltaic components.

An integrated planning process facilitates the development of optimal solutions regarding the design, function and the earnings of buildings with integrated photovoltaic generators. The requirements for the integration of photovoltaic in the building design of existing buildings as well as of new constructions can be assigned to the subject areas: adequate areas in facades and roofs, integrated design of photovoltaic, as well as building types and structural basic conditions.

Economical aspects of multifunctional and building integrated photovoltaic installations include the costs for the construction and service, as well as the profits, which can be achieved by the additional non-photovoltaic functions (e.g. cost savings for representative facades with external shading systems and blinds). Additionally financing, the value of the produced electricity and amortization influence the cost effectiveness of photovoltaic installations.

4. Conclusion:

In the past the main focus for the development of photovoltaic was initially on wafer-, module- and system-technology. Today it becomes more and more apparent that the skin of buildings provides ideal surfaces for the conversion of solar radiation in electric energy by photovoltaic systems. This particularly applies to the big available areas, which are close to the source of electrical energy demand in buildings. The outcome of this is the need of a structural integration. Such an integration of new technology in buildings is one of the most exciting tasks for planning and designing architects. The specific technical properties and aesthetical appearance of different photovoltaic technologies offer versatile options for building integrations.

The integration requires the knowledge of specific criteria of these technologies, the technical, economical and structural as well as the artistic and formal. It is obvious that these criteria have to be considered already during the first design steps. Everything, which would be introduced later would lead to technical worse solutions and would cost more money. Already in the design phase two scopes of duties have to be bridged, the design of the photovoltaic installation and the design of the building, in which the photovoltaic installation has to assume an important function. Glass facades for instance, which are constructed with semitransparent photovoltaic modules integrated into insulation glass can be designed in a way that they provide sufficient daylight and shading to the indoors. The installation of structural shading and light directing components can be avoided and the related costs can be saved. Hence, an integrated design and planning process which is considering the positive interdependencies of photovoltaic's multiple functions facilitates both, cost reductions for specific functions which can be covered by building integrated photovoltaic generators as well as new aesthetically forms of use for building designs.

5. References

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